Motion-Base Simulation Guides Future Force Systems Design

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The U.S. Army Tank and Automotive Research, Development and Engineering Center (TARDEC), in collaboration with the U.S. Army Research Laboratory (ARL), Human Research and Engineering Directorate (HRED), are using TARDEC's Ride Motion Simulator (RMS) to address design requirements for Future Force systems. These systems will be lightweight, highly mobile vehicles that will use complex information systems to ensure Soldier survivability and system lethality. A major challenge and program risk identified by Future Combat Systems is that Soldiers will need to maintain a high-performance level even when their vehicles are moving over rugged terrain. This motion-effects challenge involves a host of problems, including presenting critical information in an understandable way, implementing control devices that allow the successful completion of mission operations and reducing potential disorientation and motion sickness, all of which will be adversely affected when Soldiers are bounced around in moving vehicles. Making decisions on motion-effects issues is all the more difficult because potentially crucial design choices must be made for vehicles with unknown ride characteristics. Through the combined efforts of researchers at TARDEC and ARL HRED, a systematic approach using motion-base simulation is being used to address these challenges.

TARDEC's Ground Vehicle Simulation Laboratory (GVSL) fully powered turret systems stabilization experiments have resulted in gun turret drive improvements for M2 Bradley Fighting Vehicles (BFVs). Innovations such as this improve Soldier lethality and survivability in close combat and urban environments. Here, a patrol of 39th Brigade Combat Team BFVs and Humvees search for insurgents near Al Taji, Iraq. (U.S. Air Force photo by SSGT Ashley Brokop, 1st Combat Camera Squadron.)

History

For 20 years, TARDEC's Ground Vehicle Simulation Laboratory (GVSL) has been developing simulation capabilities with full motion-base simulators, reconfigurable crew workstations, several existing and theoretical ground combat vehicle (GCV) models and high-resolution dynamic terrain models. These facilities have produced a wealth of applied research and have fostered manned ground vehicle technology development. The GVSL produced numerous human factors assessments on crew station component technologies such as control handles and display devices. Fully powered turret systems stabilization experiments produced gun turret drive improvements in the M2 BFV.

Recently, the RMS was heavily used to evaluate Humvee seats and restraints using combat-equipped Soldiers.

TARDEC's GVSL operates various-sized simulators that can potentially accommodate as many as 9 Soldiers in a reconfigurable vehicle mock-up and are capable of generating complex 6-degree-of-freedom motions of payloads up to 25 tons. Furthermore, GVSL has developed detailed models of GCVs including the Stryker, Humvee and a futuristic 24-ton tracked vehicle with ride characteristics that can be reproduced through high-fidelity computer simulations. These simulations also use dynamic terrain models developed through programs such as the High-Resolution Virtual Terrain Small Business Innovative Research and the High-Fidelity Ground Platform and Terrain Mechanics (HGTM) Army Technology Objective (ATO). These models include environmental factors such as wind, mud and snow, allowing for more realistic interactions between vehicles and the environment.

For example, when a vehicle passing over terrain compacts the soil, a second vehicle passing over the same terrain section will experience a different ride characteristic. The combination of platforms, and vehicle and terrain models, allows a wide range of vehicles, terrain and crew members (gunner, commander or driver) to be simulated and re-created, allowing researchers to examine each Soldier's performance within highly controlled, realistic operational environments.

The Necessity of Motion-Base Simulation

Ensuring that future Soldiers will be able to perform while the vehicles are on the move is critical to the successful development of Future Force manned GCVs. Previous research has made it clear that motion effects issues can only be addressed by looking at Soldier performance in motion environments, because conclusions and design recommendations obtained in stationary environments may not provide optimal solutions for Soldiers-on-the-move or in combat situations. There are three primary benefits of using motion-base simulators to augment actual in-vehicle testing:

- *Laboratory Control* — Better definition and repeatability are two of the major advantages for research and assessment gained by using simulators. Motion-base simulators can be used to carefully define rich environments and precise scenarios that can be repeated exactly, which is difficult, if not impossible, in real-world environments. This is crucial to ensure the validity of experimental findings.
- *Evaluation Prior to Construction* — Faster feedback on design decisions is critical. One of the most difficult problems for Future Force systems design is assessing motion effects on vehicles that don't yet exist and, importantly, have yet unknown ride qualities. Using simulations, vehicle models can be constructed from known or proposed future vehicle parameters such as suspension, drive and weight. Simulations can also be used to generate the predicted motions of future vehicle designs within motion-base simulators. Soldier performance can be examined and important feedback can be provided early in the design process before metal is bent.
- *Efficient Use of Resources* — Simulation can provide both resource and time-effective (see above) proving grounds for examining design alternatives, including Soldier-in-the-loop experimentation. Motion-base simulation offers the ability to solve many initial problems, such as vehicle motion effects, in a more effective manner by evaluating different design solutions before expensive prototypes are constructed and critical resources are spent in lengthy and costly field testing. Ultimately, more efficient evaluation of design alternatives can be achieved.

A participant operates the CAT mounted on the RMS during a recent experiment. TARDEC and ARL use the simulator to test issues including the effects of ground vehicle motion environments on Soldier performance. For illustration purposes, the crew station is opened. However, for testing purposes, the crew station can be enclosed to simulate a "buttoned-up" environment. (Photo courtesy of TARDEC.)

Over the past three years, TARDEC has teamed with ARL to specifically examine Soldier performance issues within these motion-base environments. Using a simulator and monitor control system integrating scenario design, and operation and data acquisition, researchers have examined the field-of-view influences on driving performance and ground vehicle motion effects on reach accuracy for the Crew Integration and Automation Testbed-Advanced Technology Demonstrator (CAT-ATD) program. For the HGTM ATO, TARDEC and ARL researchers looked at issues including ground vehicle motion environment effects on Soldier performance on control-type tasks and evaluating potential mitigations for motion sickness.

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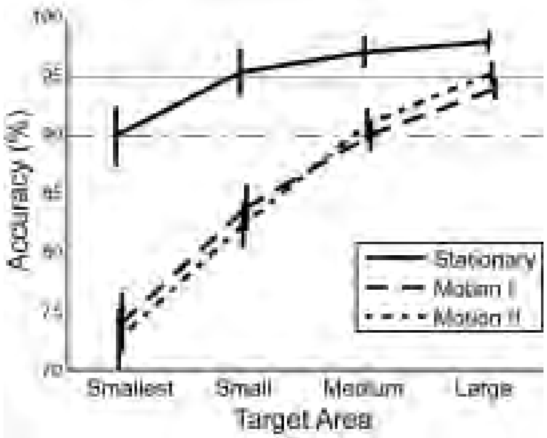
Modifying Military Standards

In a joint project, the University of Michigan, TARDEC and ARL used motion-base simulation to conduct research supporting design criteria refinements stated in *Military Standard 1472 Design Criteria Standard, Human Engineering, 1999*. This project specifies button-size design for Soldier-machine interfaces. TARDEC's midsize motion-base platform, the RMS, which supports a reconfigurable cab large enough to allow simulation of a single-occupant crew station outfitted with vehicle controls, displays and seats with restraints, was used to conduct research to determine the appropriate button size for Soldiers operating touch-screen displays while on the move. The study had a twofold purpose: to examine vehicle motions that will affect Soldiers' reach to operate buttons on an interface and to examine the operation of touch-screen interfaces that are advantageous for their design flexibility, but problematic because operators cannot feel when a button has been pressed.

Participants were asked to press different sized touch-screen and physical



An RMS study supports the need for increased button sizes to operate touch screens in motion environments.

buttons in the RMS cab while experiencing a stationary and two types of motion environments. The results obtained, using an advanced motion-capture camera system, showed that participants' reaching movements were degraded in timing and accuracy during RMS cab movement, as compared to when it was stationary. The study (see figure above) suggests that increasing button size should increase performance accuracy.

The experiment results, using motion-base simulation, are consistent with anecdotal evidence derived from the CAT-ATD, a joint TARDEC-ARL program that examines advanced crew station design within field environments. Crew station tests in the CAT-ATD have suggested touch-screen display applications within motion environments require larger buttons located next to bezels for stabilization points for the operator. The combination of empirical evidence from the RMS study with the practical application of the CAT-ATD program suggests that either larger button sizes or another form of mitigation (stabilization points, modifying vehicle ride quality) will be required to obtain sufficient accuracy goals during operations-on-the-move in Future Force systems.

Pictured is a CAT-ATD advanced crew station, where increased button size was used for in-field testing. (Photo courtesy of Lockheed Martin.)

This example shows how research results can be translated into design recommendations that have been proven in actual field evaluations. Particularly important is that existing human engineering standards for interface designs that work well for Soldiers in stationary environments may need to be reevaluated when they are used in moving vehicles. Motion-base simulators like TARDEC's RMS provide a useful environment for examining these issues.

The TARDEC motion-base RMS addresses Soldier performance issues for future systems design. The motion simulator provides a means for efficient, controllable and repeatable assessment to examine motion issues that will affect Soldiers as they are performing their missions on the move. Finding solutions to this challenge will be critical to the success of Future Force systems. Through the combined use of high-fidelity motion-base simulation and fielded prototypes such as CAT-ATD, TARDEC and ARL are conducting the research necessary to acquire the right information so the best decisions can be made to produce the most effective systems for our Soldiers.

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